Ultralow-Power Consumption Photonic Synapse Transistors Based on Organic Array Films Fabricated by Particular Prepatterned-Guided Crystallizing Strategy

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Supporting Information

Captions

Figure S1 (a) The schematic diagram of the prepatterned-guided crystal-growth method. Schematic diagram of precursor solution drying method and crystal growth

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method on the substrate without **(b)** and with **(c)** prepattern.

Figure S2 The morphology of TIPS-pentacene/PS film fabricated on the substrate without **(a)** and with **(b)** array pattern. The AFM image of intergranular crack between different crystals **(c)** and the grain boundary on the surface of the large grains **(d)**.

Figure S3 The transfer curve of the transistors with the channel in the same crystal region **(a)**, with the grain boundary of two isotropic crystals **(b)**, and with the grain boundary of two extruded crystals **(c)**.

Figure S4 The color map of the μ_{FET} **(a)** and the current on/off ratio **(b)** of 8×8 TIPS-pentacene transistor arrays with patterned-less film. The statistical heat map of the μ_{FET} **(c)** and the current on/off ratio **(d)** of the transistors.

Table S1 Performance comparison of TIPS-pentacene/PS transistors with prepattern and no pattern.

Table S2 Comparison of electrical parameters of TIPS-pentacene organic thin film transistors fabricated by drop-coating or inkjet-printed.

Figure S5 The source-drain current and the gate current of the transistor with perpendicular direction to the array films.

Figure S6 The transfer curve of the array TIPS-pentacene/PS films-based transistor without **(a)** and with **(b)** $CsPbBr_3$ QDs.

Figure S7 The AFM image of the surface of the pattern-less TIPS-pentacene/PS film **(a)**, the array TIPS-pentacene/PS film **(b)**, and the array TIPS-pentacene/PS/CPBQDs film **(c)**.

Figure S8 The source-drain curves of ternary transistor under dark and with light illumination.

Figure S9 (a) The peak photocurrent after illumination being removed under different light power. **(b)** The peak photocurrent after illumination being removed under different light pulse duration.

Figure S10 The EPSC of TIPS-pentacene/PS transistor.

Figure S11 The EPSC with V_{DS} of -0.01 V, -0.001 V and -0.0001 V.

Table S3 A summarized list of operation parameters and the power consumption of photonic synaptic per event with perovskite and organic materials.

Figure S12 (a) The peak photocurrent after illumination being removed under different light pulse duration. **(b)** The decay photocurrent of synapse and the fitting curve of the stretched-exponential function.

Table S4 Comparison of the retention characteristics with previously reported photonic synaptic devices.

Table S5 Comparison of the retention characteristics of ternary composite synapses with different incident light pulse width, number, and frequency.

Figure S13 The schematic diagram of the operating mechanism of ternary synaptic device under light illumination **(a)** and negative gate voltage **(b)**.

Figure S14 (a) The EPSC of the TIPS-pentacene/PS transistor with and without $CsPbBr_3$ QDs in V_{DS} of -1 V. (b) The EPSC of the TIPS-pentacene/ $CsPbBr_3$ QDs transistor in V_{DS} of -10 V.

Figure S15 (a) The morphology of TIPS-pentacene/ $CsPbBr_3$ QDs film without array

pattern. **(b)** The transfer curve of the TIPS-pentacene/ $CsPbBr_3$ QDs films transistor. **(c)** The morphology of TIPS-pentacene/ $CsPbBr_3$ QDs film without array pattern under blue light. **(d)** The morphology of TIPS-pentacene/PS/CPBQDs film with array pattern under blue light.

Figure S16 (a) Multitude cycles of 10 consecutive light pulses. **(b)** Multitude cycles of 10 consecutive electric pulses. **(c)** Multitude cycles of light potentiation and electric depression of ternary synapse.

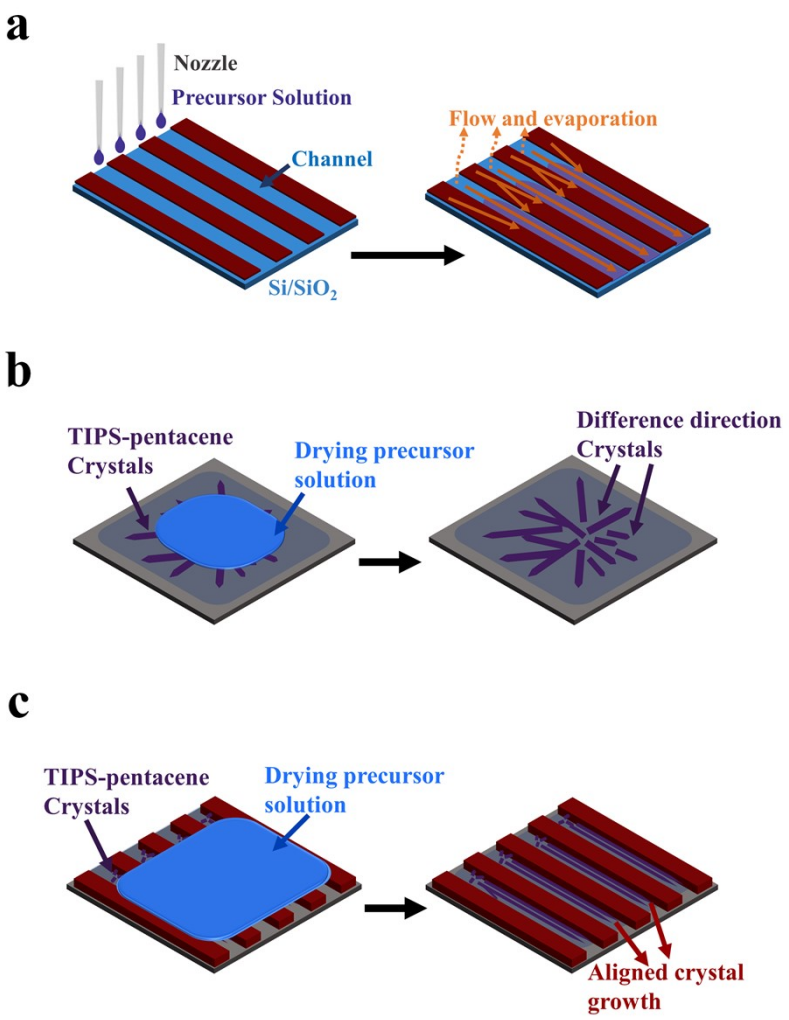
a
Nozzle
Precursor Solution
Channel
Si/SiO2
Flow and evaporation
b
TIPS-pentacene
Crystals
Drying precursor
solution
Difference direction
Crystals
c
TIPS-pentacene
Crystals
Drying precursor
solution
Aligned crystal
growth

Figure S1

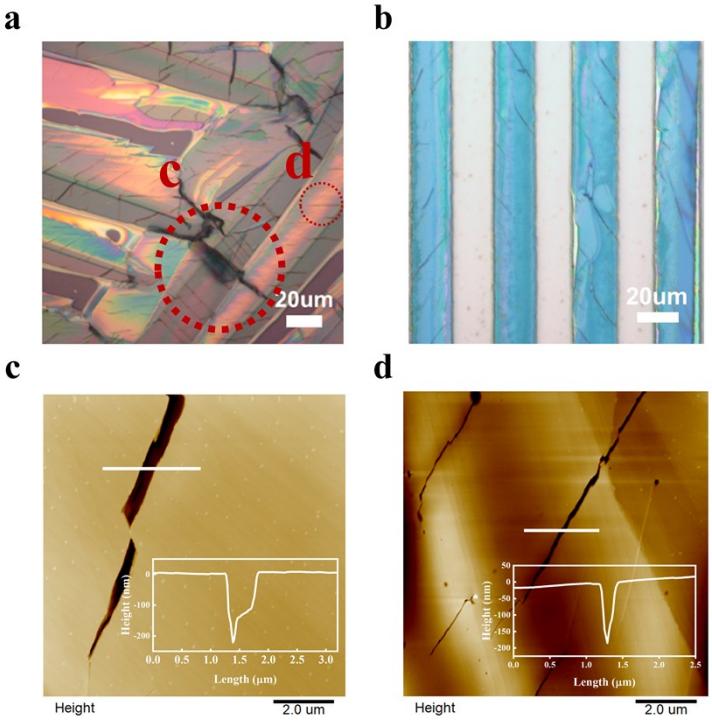
a
b
c
d
20um
20um
Height (nm)
Length (μm)
Height
2.0 um
Height (nm)
Length (μm)
Height
2.0 um

Figure S2

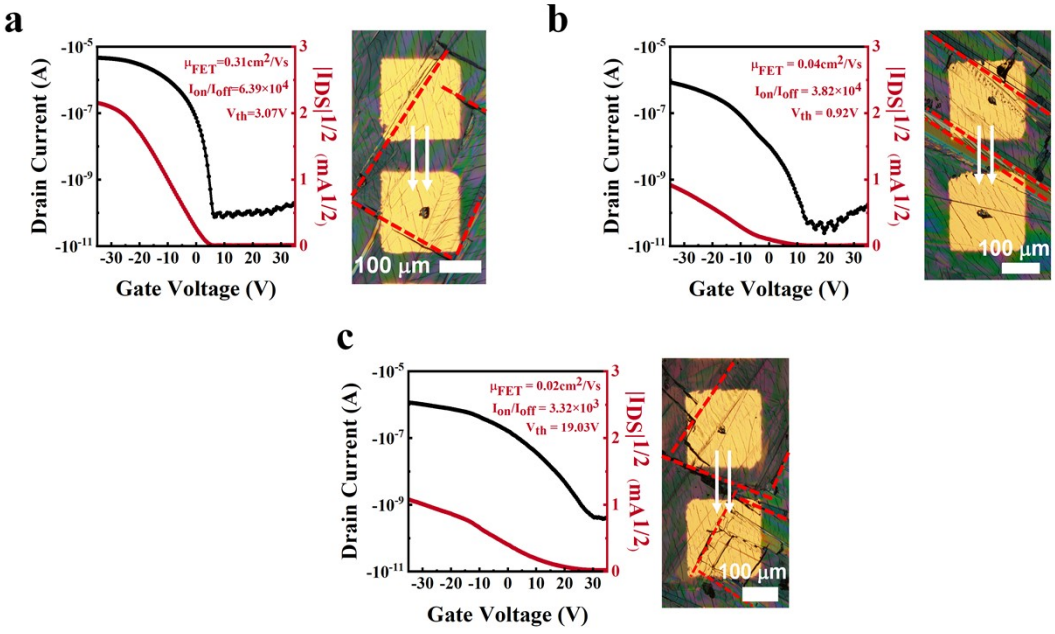
a
Drain Current (A)
Gate Voltage (V)
|IDS|1/2 (mA1/2)
μFET=0.31cm2/Vs
Ion/Ioff=6.39×10^4
Vth=3.07V
100 μm
b
Drain Current (A)
Gate Voltage (V)
|IDS|1/2 (mA1/2)
μFET = 0.04cm2/Vs
Ion/Ioff = 3.82×10^4
Vth = 0.92V
100 μm
c
Drain Current (A)
Gate Voltage (V)
|IDS|1/2 (mA1/2)
μFET = 0.02cm2/Vs
Ion/Ioff = 3.32×10^3
Vth = 19.03V
100 μm

Figure S3

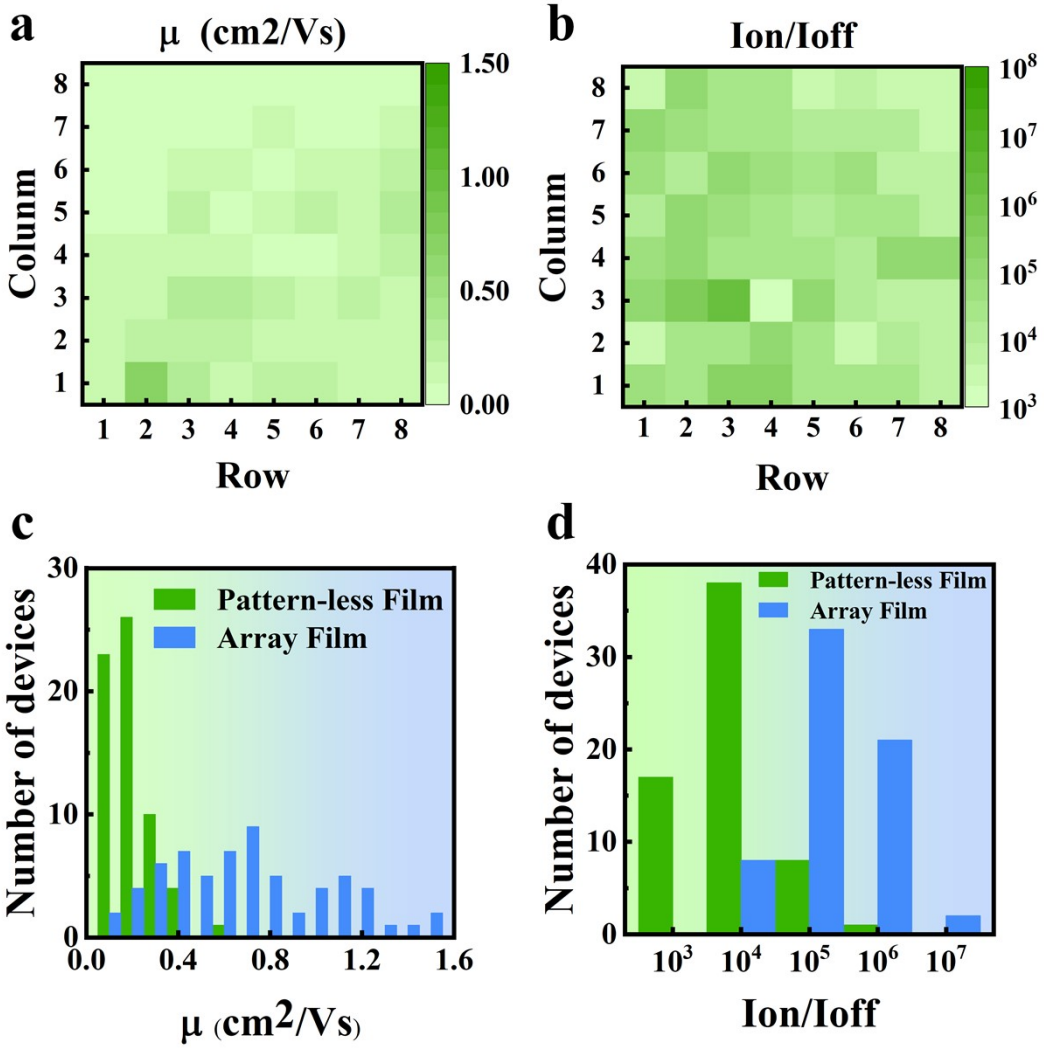
a
μ (cm2/Vs)
Column
Row
1.50
1.00
0.50
0.00
b
Ion/Ioff
Column
Row
c
Number of devices
Pattern-less Film
Array Film
μ (cm2/Vs)
d
Number of devices
Pattern-less Film
Array Film
Ion/Ioff

Figure S4

Table S1

Preparation Method	μ (cm^2/Vs)		I_{on}/I_{off}
	Average	Max.	
Pattern-less	0.150 ± 0.014	0.658	$>10^6$
Prepattern	0.637 ± 0.354	1.473	$>10^7$

Table S2

Precursor	Solvent	Dielectric	Electrode W/L (um)	μ (cm^2/Vs)	I_{on}/I_{off}	Ref.
TIPS-pentacene: PS	Toluene	HfO_2	700/94	0.44	~10^5	[1]
SiO_2 nanoparticle/ TIPS-pentacene	Toluene	SiO_2	2000/50	0.1	~10^5	[2]
TIPGe-pentacene	Toluene	AlO_x	3000/45	0.4	~10^5	[3]
TIPS-pentacene	Tetralin	PS Brushes	100/30	1.2	1.2×10^7	[4]
TIPS-pentacene	Hexane	PVDF-TrFE	--	1	>10^5	[5]
TIPS-pentacene	Hexane	PMMA	1000/50	~1	>10^6	[6]
TIPS-pentacene: PS	Chlorobenzene	PVC	--	0.6	~10^6	[7]
TIPS-pentacene	Chlorobenzene	PVA	--	0.79	~10^4	[8]
TIPS-pentacene: PS	Anisole	SiO_2	1000/80	1.3	>10^5	[9]
TIPS-pentacene: PS	**Toluene**	**SiO_2**	**1000/100**	**1.47**	**5.8×10^7**	**This work**

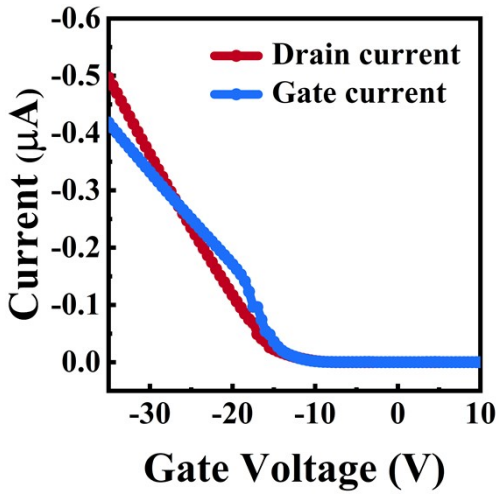
Drain current
Gate current
Current (μA)
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0.0
-30
-20
-10
0
10
Gate Voltage (V)

Figure S5

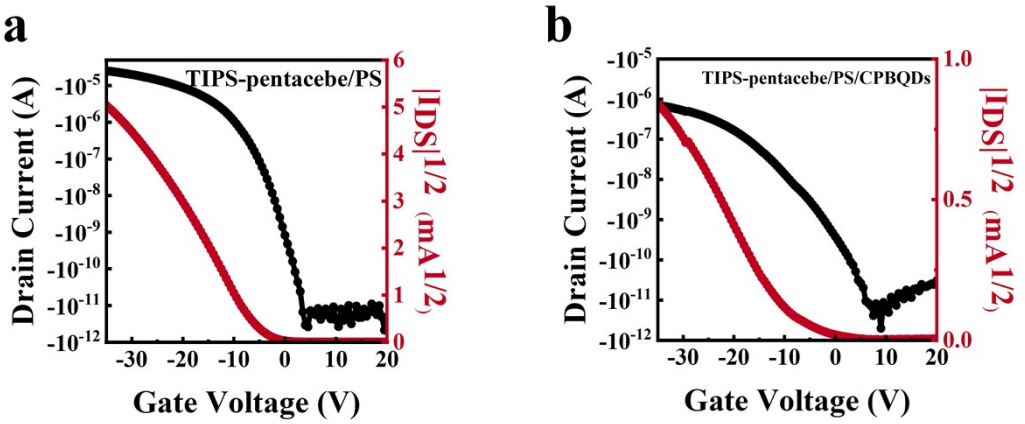
a
TIPS-pentacebe/PS
Drain Current (A)
|IDS|1/2 (mA1/2)
Gate Voltage (V)
b
TIPS-pentacebe/PS/CPBQDs
Drain Current (A)
|IDS|1/2 (mA1/2)
Gate Voltage (V)

Figure S6

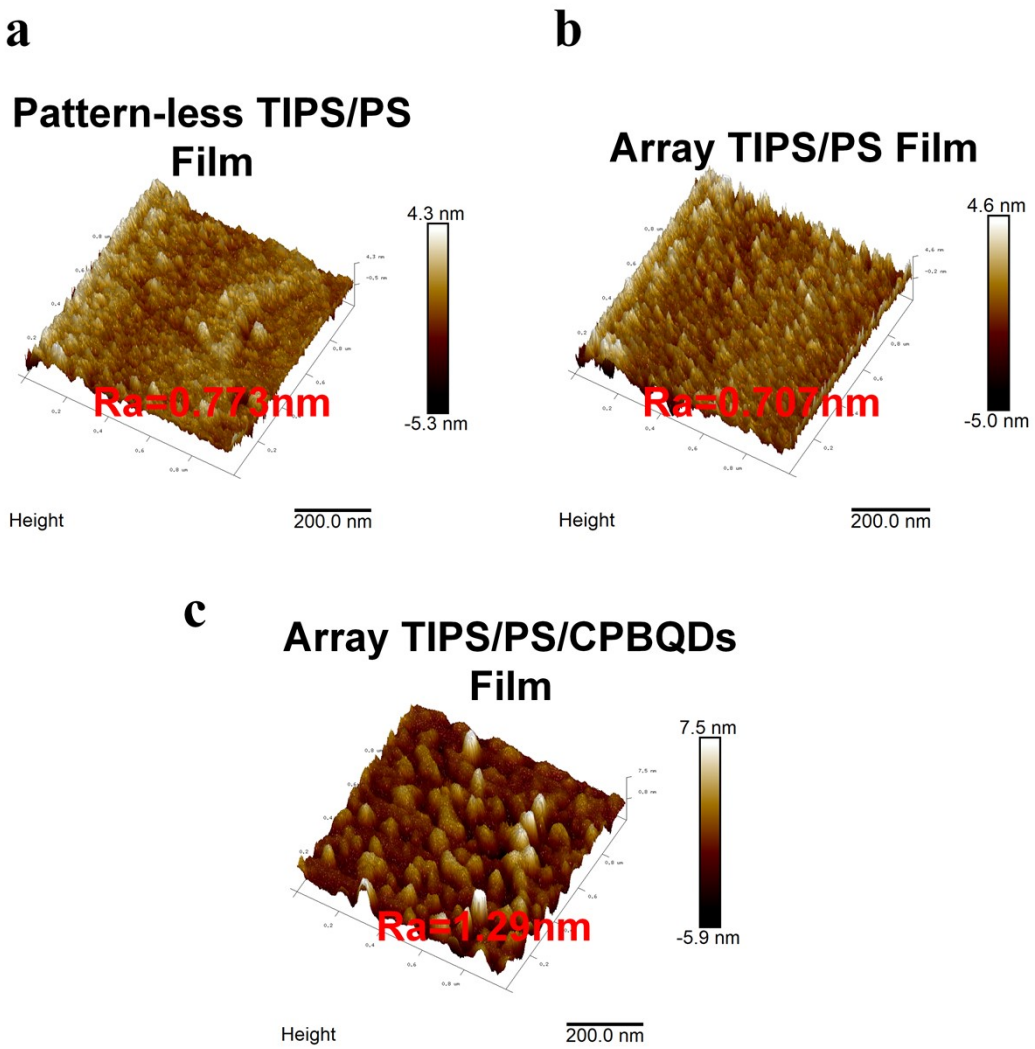
a
Pattern-less TIPS/PS Film
4.3 nm
-5.3 nm
Ra=0.773nm
Height
200.0 nm
b
Array TIPS/PS Film
4.6 nm
-5.0 nm
Ra=0.707nm
Height
200.0 nm
c
Array TIPS/PS/CPBQDs Film
7.5 nm
-5.9 nm
Ra=1.29nm
Height
200.0 nm

Figure S7

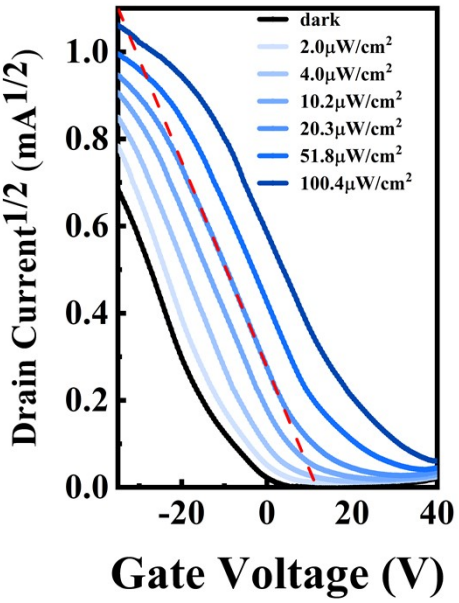
dark
2.0μW/cm²
4.0μW/cm²
10.2μW/cm²
20.3μW/cm²
51.8μW/cm²
100.4μW/cm²
Drain Current^1/2 (mA^1/2)
1.0
0.8
0.6
0.4
0.2
0.0
-20
0
20
40
Gate Voltage (V)

Figure S8

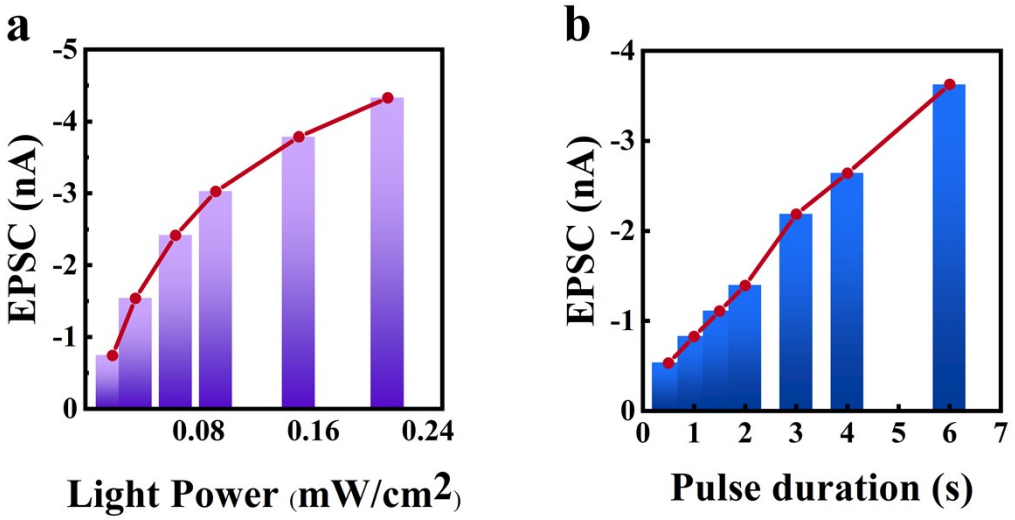
a
EPSC (nA)
-5
-4
-3
-2
-1
0
0.08
0.16
0.24
Light Power (mW/cm2)
b
EPSC (nA)
-4
-3
-2
-1
0
0
1
2
3
4
5
6
7
Pulse duration (s)

Figure S9

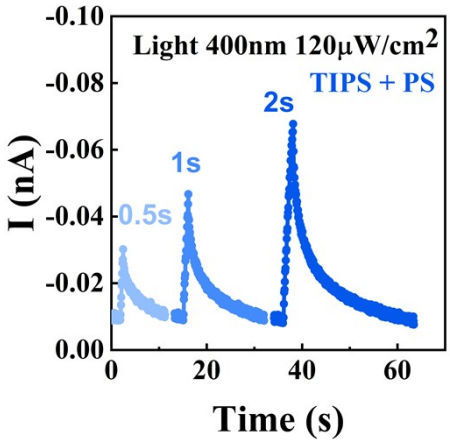
Light 400nm 120μW/cm2
TIPS + PS
2s
1s
0.5s
I (nA)
-0.10
-0.08
-0.06
-0.04
-0.02
0.00
0
20
40
60
Time (s)

Figure S10

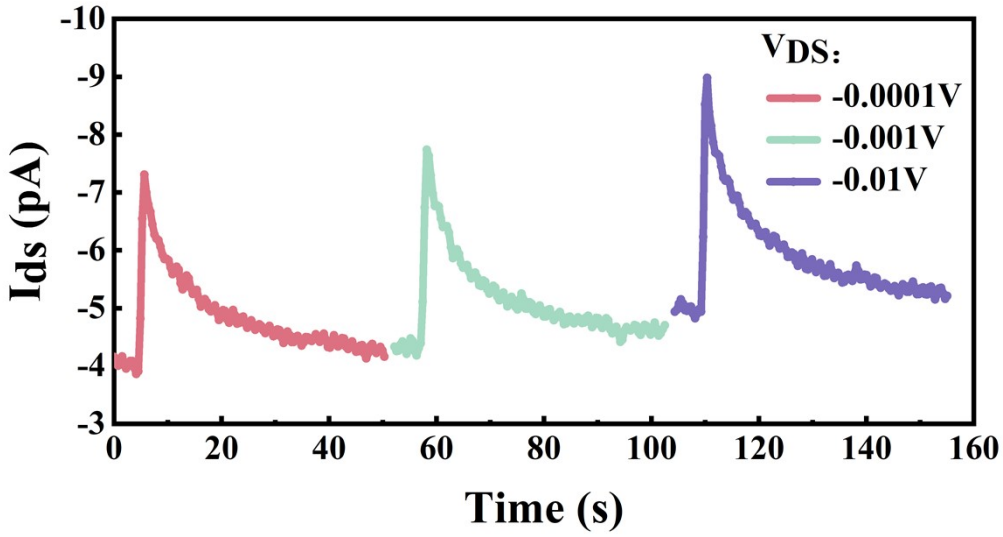
-10
-9
-8
-7
-6
-5
-4
-3
Ids (pA)
0
20
40
60
80
100
120
140
160
Time (s)
VDS:
-0.0001V
-0.001V
-0.01V

Figure S11

Table S3

Material	Reading voltage [V]	Light Duration [ms]	Light Intensity [μW cm^{-2}]	Power Consumption [fJ]	Ref.
DPPDTT/$CsPbBr_3$ QDs	-5×10^{-4}	50	50	0.5	[10]
$CsPbBr_3$ QDs/P_3HT	-0.001	-	-	0.18	[11]
P_3HT/$FAPbBr_3$ QDs	-5×10^{-4}	50	6000	0.03	[12]
MAPbBr3/PS/Pentacene	-1	50	420	5800	[13]
$CsPbBr_3$ film/ TIPS-Pentacene	-0.01	~200	46	76	[14]
C_8-BTBT/PS/ $CsPbBr_3$ QDs	-0.01	10	0.5	0.11	[15]
MAPbBr3-RhB /Pentacene	-5×10^{-5}	1000	58	1.25	[16]
TIPS-Pentacene/PS/ $CsPbBr_3$ QDs	**-1×10^{-4}**	**50**	**25**	**0.036**	**This work**

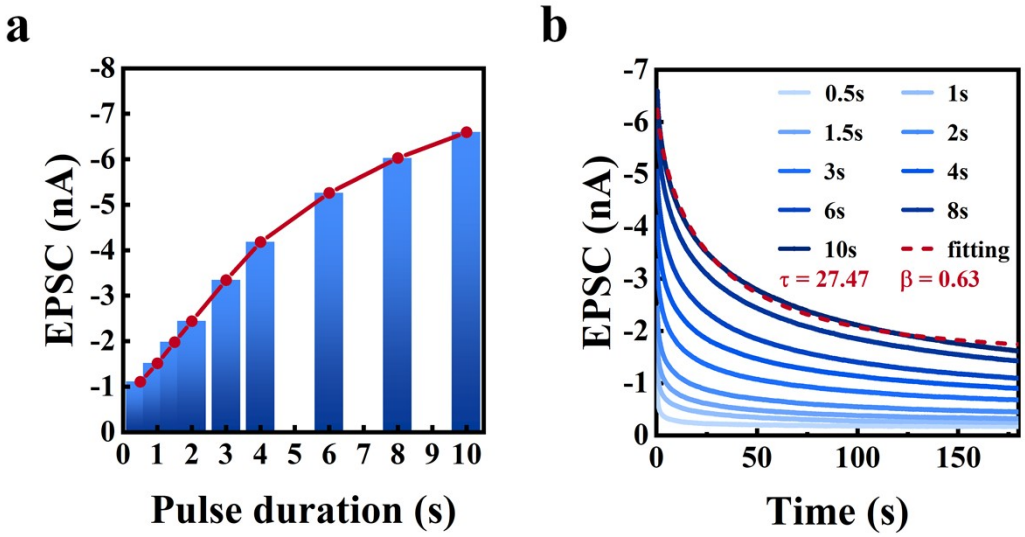
a
b
EPSC (nA)
Pulse duration (s)
EPSC (nA)
Time (s)
0.5s
1s
1.5s
2s
3s
4s
6s
8s
10s
fitting
τ = 27.47
β = 0.63

Figure S12

Table S4

Material	τ(s)	β	Light stimulation condition				Ref.
			Wavelength (nm)	Power (mW/cm^2)	Frequency or duration	Pulse number	
amorphous Si	18.29	0.49	450	110	> 15s	1	[17]
C8-BTBT/PAN	0.685		360	0.9	0.2s	1	[18]
HfS_2	0.128	0.354	405	43.3	0.5s	1	[19]
M-QD/α-IGZO	27.1 65.2 18.2	0.51 0.67 0.4	405 519 635	5	2.5Hz	30	[20]
TIPS-Pentacene/PS/ $CsPbBr_3$ QDs	**27.47**	**0.63**	**450**	**0.2**	**10s**	**1**	**This work**

Table S5

Duration [s]	τ**(s)**	β	**Number [#]**	τ**(s)**	β	**Frequency [Hz]**	τ**(s)**	β
0.5	1.33	0.35	**1**	16.43	0.90	**0.1**	9.87	0.45
1	5.04	0.43	**2**	20.29	0.83	**0.2**	11.33	0.46
1.5	7.09	0.45	**4**	31.30	0.95	**1**	11.71	0.46
2	10.47	0.48	**6**	36.98	0.99	**2**	13.31	0.48
3	14.17	0.52	**8**	40.98	1.04	**5**	17.11	0.52
4	17.53	0.55	**10**	43.65	1.05			
6	20.66	0.59						
8	25.01	0.62						
10	27.47	0.63						

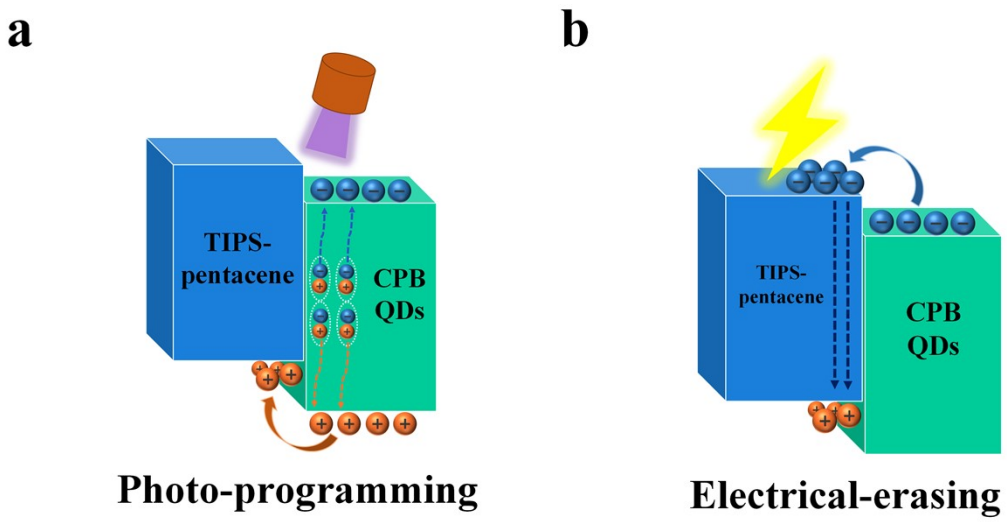
a
b
TIPS-
pentacene
CPB
QDs
TIPS-
pentacene
CPB
QDs
Photo-programming
Electrical-erasing

Figure S13

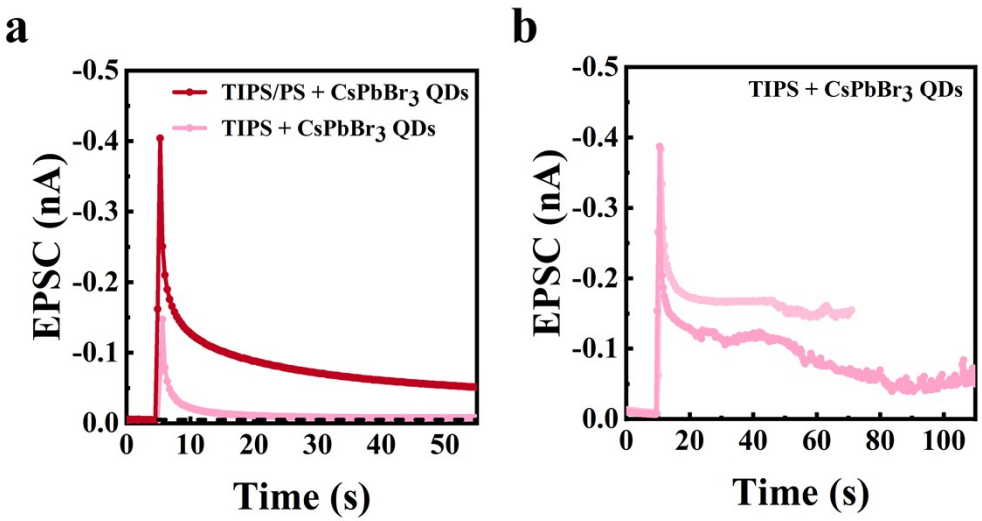
a
b
TIPS/PS + CsPbBr3 QDs
TIPS + CsPbBr3 QDs
EPSC (nA)
Time (s)
-0.5
-0.4
-0.3
-0.2
-0.1
0.0
0
10
20
30
40
50
60
80
100

Figure S14

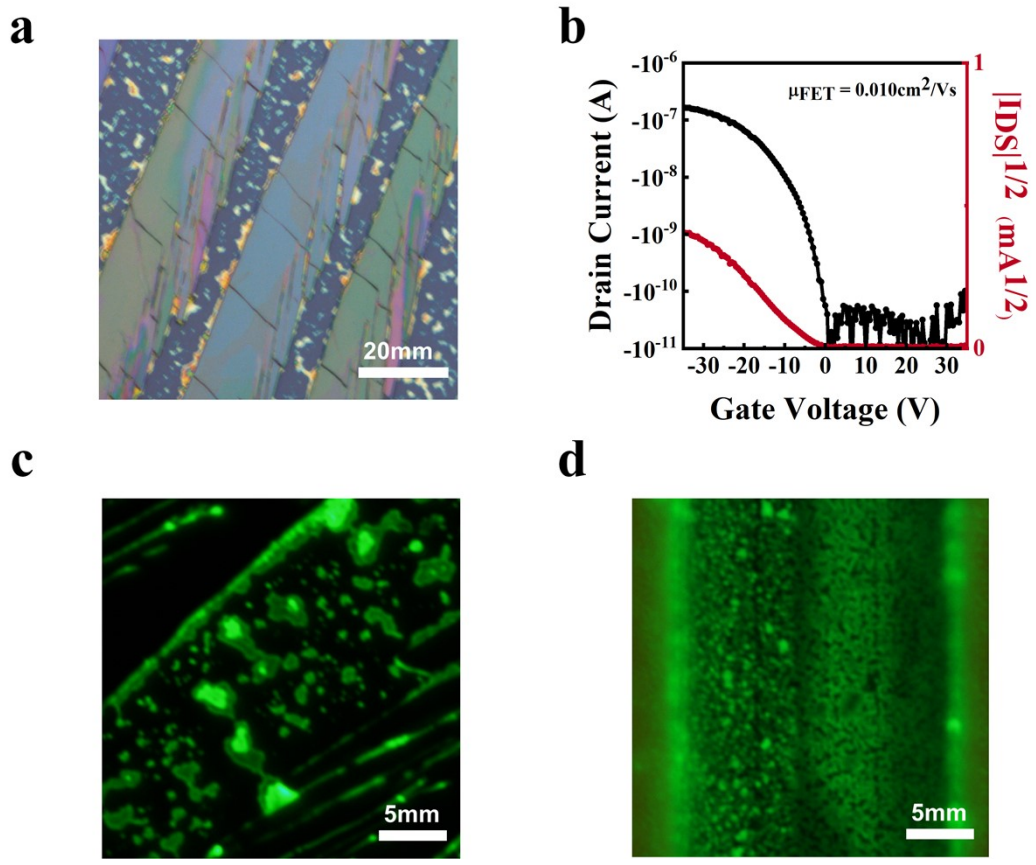
a
20mm
b
μFET = 0.010cm2/Vs
Drain Current (A)
-10-6
-10-7
-10-8
-10-9
-10-10
-10-11
-30 -20 -10 0 10 20 30
Gate Voltage (V)
|IDS|1/2 (mA1/2)
1
0
c
5mm
d
5mm

Figure S15

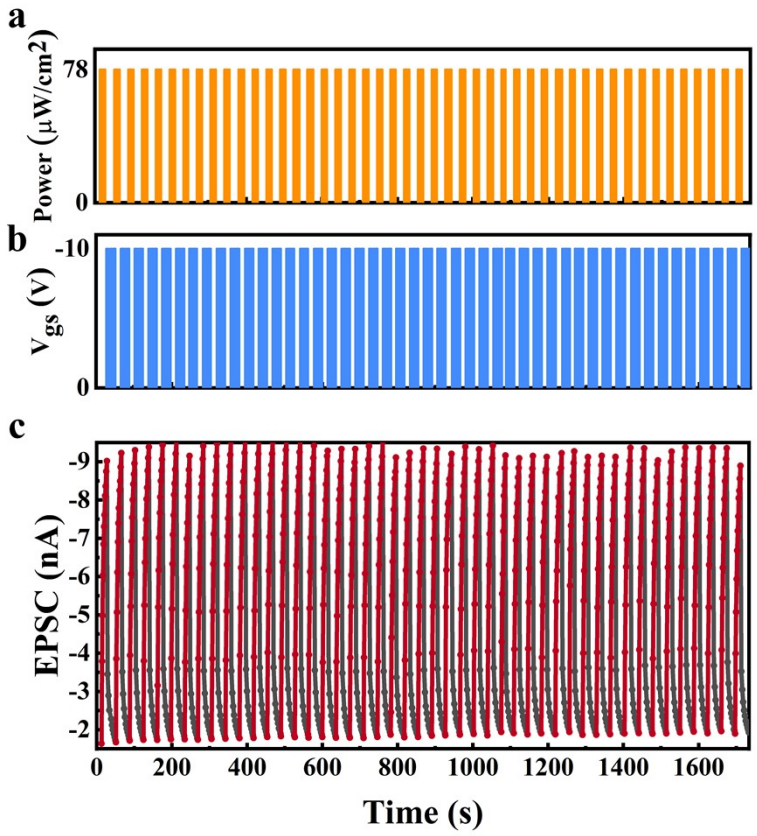
a
Power (μW/cm²)
78
0
b
V_gs (V)
-10
0
c
EPSC (nA)
-9
-8
-7
-6
-5
-4
-3
-2
0
200
400
600
800
1000
1200
1400
1600
Time (s)

Figure S16

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